

METODE ISPITIVANJA I TEHNIČKI USLOVI ZA SISTEME ŠINSKIH PRIČVRŠĆENJA ZA BETONSKE PRAGOVE

TEST METHODS AND REQUIREMENTS FOR FASTENING SYSTEMS FOR CONCRETE SLEEPERS

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1 UVOD

Harmonizacija tehničke regulative u oblasti železničke infrastrukture još uvek je u toku u Republici Srbiji. Evropski komitet za standardizaciju (*European Committee for Standardization - CEN*) izradio je seriju standarda EN 13481 – *Primene na železnici – Kolosek – Tehnički uslovi za sisteme pričvršćenja*, koja se sastoji iz sledećih osam delova:

- Deo 1: Definicije [1];
- Deo 2: Sistemi šinskih pričvršćenja za betonske pragove [2];
- Deo 3: Sistemi šinskih pričvršćenja za drvene pragove [3];
- Deo 4: Sistemi šinskih pričvršćenja za čelične pragove [4];
- Deo 5: Sistemi šinskih pričvršćenja za konstrukciju koloseka bez zastora, sa šinom položenom na gornju površinu ili u kanalu ploče [5];
- Deo 6 (nacrt evropskog standarda): Specijalni sistemi šinskih pričvršćenja za prigušenje vibracija [6];
- Deo 7: Specijalni sistemi šinskih pričvršćenja za skretnice, ukrštaje i šine vođice [7];

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1 INTRODUCTION

Harmonization of technical regulation in the area of railway infrastructure is still in progress in the Republic of Serbia. European Committee for Standardization (CEN) has created a group of standards EN 13481 - *Railway applications - Track - Performance requirements for fastening systems*, which consists of eight parts as listed below:

- Part 1: Definitions [1],
- Part 2: Fastening systems for concrete sleepers [2],
- Part 3: Fastening systems for wood sleepers [3],
- Part 4: Fastening systems for steel sleepers [4],
- Part 5: Fastening systems for slab track with rail on the surface or rail embedded in a channel [5],
- Part 6 (European Prestandard): Special fastening systems for attenuation of vibration [6],
- Part 7: Special fastening systems for switches and crossings and check rails [7],
- Part 8: Fastening systems for track with heavy axle loads [8].

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– Deo 8: Sistemi šinskih pričvršćenja za velika osovinska opterećenja [8].

Gorepomenute delove – od 1 do 8 – usvojio je Institut za standardizaciju Srbije (ISS) [9], kao što je prikazano u tabeli 1. Srpska serija standarda SRPS EN 13481 identična je sa evropskom serijom standarda EN 13481.

Pored toga, serija standarda EN 13146 – *Primene na železnici – Kolosek – Postupci ispitivanja sistema šinskih pričvršćenja* podržava zahteve iz serije EN 13481 i sastoji se iz sledećih delova:

- Deo 1: Određivanje otpora podužnom pomeranju šine [10];
- Deo 2: Određivanje otpora zaokretanju šine [11];
- Deo 3: Određivanje prigušenja udarnog opterećenja [12];
- Deo 4: Ispitivanje uticaja ponavljanja opterećenja [13];
- Deo 5: Određivanje električnog otpora [14];
- Deo 6: Uticaj agresivne sredine [15];
- Deo 7: Određivanje sile pritezanja [16];
- Deo 8: Ispitivanje pod saobraćajem [17];
- Deo 9: Određivanje krutosti [18].

Delovi od 1 do 9 serije standarda EN 13146 usvojio je ISS [19], kao što je prikazano u tabeli 2. Srpska serija standarda SRPS EN 13146 identična je sa evropskom serijom standarda EN 13146.

The above mentioned parts 1 - 8 are adopted by the Institute for standardization of Serbia (ISS) [9], as shown in Table 1. SRPS EN 13481 Serbian standard series is identical with EN 13481 European Standard series.

In addition, EN 13146 - *Railway applications - Track - Test methods for fastening systems* supports the requirements defined in EN 13481 series and consists of the following parts:

- Part 1: Determination of longitudinal rail restraint [10],
- Part 2: Determination of torsional resistance [11],
- Part 3: Determination of attenuation of impact loads [12],
- Part 4: Effect of repeated loading [13],
- Part 5: Determination of electrical resistance [14],
- Part 6: Effect of severe environmental conditions [15],
- Part 7: Determination of clamping force [16],
- Part 8: In service testing [17],
- Part 9: Determination of stiffness [18].

The parts 1 - 9 of EN 13146 standard series are adopted by the ISS [19], as shown in Table 2. SRPS EN 13146 Serbian standard series is identical with the EN 13146 European Standard series.

Tabela 1. Trenutno stanje srpske serije standarda SRPS EN 13481 prema [9]
Table 1. The latest stage of SRPS EN 13481 Serbian standard series according to [9]

Srpska oznaka standarda, naslov (Serbian standard designation, title)	Status u Srbiji (Status in Serbia)	Identičan kao evropski standard (Identical with European standard)
SRPS EN 13481-1:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 1: Definicije	Objavljen (Published) 24.06.2013	EN 13481-1:2012, Railway applications - Track - Performance requirements for fastening systems - Part 1: Definitions [1]
SRPS EN 13481-2:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 2: Sistemi šinskih pričvršćenja za betonske pragove		EN 13481-2:2012, Railway applications - Track - Performance requirements for fastening systems - Part 2: Fastening systems for concrete sleepers [2]
SRPS EN 13481-3:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 3: Sistemi šinskih pričvršćenja za drvene pragove		EN 13481-3:2012, Railway applications - Track - Performance requirements for fastening systems - Part 3: Fastening systems for wood sleepers [3]
SRPS EN 13481-4:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 4: Sistemi šinskih pričvršćenja za čelične pragove		EN 13481-4:2012, Railway applications - Track - Performance requirements for fastening systems - Part 4: Fastening systems for steel sleepers [4]
SRPS EN 13481-5:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 5: Sistemi šinskih pričvršćenja za konstrukciju koloseka bez zastora sa šinom položenom na gornju površinu ili u kanalu ploče		EN 13481-5:2012, Railway applications - Track - Performance requirements for fastening systems - Part 5: Fastening systems for slab track with rail on the surface or rail embedded in a channel [5]
SRPS ENV 13481-6:2012, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 6: Specijalni sistemi šinskih pričvršćenja za prigušenje vibracija	Povučen (Withdrawn) 31.01.2014	ENV 13481-6:2002, Railway applications - Track - Performance requirements for fastening systems - Part 6: Special fastening systems for attenuation of vibration [6]
SRPS EN 13481-7:2013, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 7: Specijalni sistemi šinskih pričvršćenja za skretnice, ukrštaje i šine vođice	Objavljen (Published) 24.06.2013	EN 13481-7:2012, Railway applications - Track - Performance requirements for fastening systems - Part 7: Special fastening systems for switches and crossings and check rails [7]
SRPS EN 13481-8:2011, Primene na železnici - Kolosek - Tehnički uslovi za sisteme šinskih pričvršćenja - Deo 8: Sistemi šinskih pričvršćenja za velika osovinska opterećenja	Povučen (Withdrawn) 31.01.2014	EN 13481-8:2006, Railway applications - Track - Performance requirements for fastening systems - Part 8: Fastening systems for track with heavy axle loads [8]

Usvojene serije standarda SRPS EN 13481 i SRPS EN 13146 nisu prevedene na srpski jezik, izuzev naslova i oblasti važenja. Značajna prepreka za efikasnu primenu usvojenih standarda SRPS EN u inženjerskoj praksi jeste nepostojanje njihovog zvaničnog prevoda na srpski jezik.

S obzirom na veliko interesovanje inženjerske stručne javnosti za ovu temu, ovaj rad jeste opširnija verzija rada koji su autori uspešno predstavili na međunarodnoj konferenciji RAILCON 2016 u Nišu, 13. oktobra 2016. godine [20].

U ovom radu razmatraju se tehnički zahtevi za sisteme šinskih pričvršćenja na prugama s projektovanim osovinskim opterećenjem do 350 kN, u skladu sa serijama standarda SRPS EN 13481 i SRPS EN 13146.

The adopted SRPS EN 13481 and SRPS EN 13146 standard series are not translated into Serbian language, except the titles and scopes. Significant obstacle to the effective implementation of the adopted SRPS EN standards in engineering practice is the lack of official translation in Serbian language.

Since there was a great interest by the engineering public for the subject, this paper is the wider version of the paper presented at the International conference RAILCON 2016 held in Niš, Serbia on 13th of October, 2016 [20].

In this paper, performance requirements for rail fastening systems on rail lines axle load up to 350 kN were considered according to the adopted SRPS EN 13481 and SRPS EN 13146 standard series.

Tabela 2. Trenutno stanje srpske serije standarda SRPS EN 13146 prema [19]
Table 2. The latest stage of SRPS EN 13146 Serbian standard series according to [19]

Srpska oznaka standarda, naslov (<i>Serbian standard designation, title</i>)	Status u Srbiji (<i>Status in Serbia</i>)	Identičan kao evropski standard (<i>Identical with European standard</i>)
SRPS EN 13146-1:2015, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 1: Određivanje otpora podužnom pomeranju šine	Objavljen (<i>Published</i>) 28.07.2015	EN 13146-1:2012+A1:2014, Railway applications - Track - Test methods for fastening systems - Part 1: Determination of longitudinal rail restraint [10]
SRPS EN 13146-2:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 2: Određivanje otpora zaokretanju šine	Objavljen (<i>Published</i>) 24.06.2013	EN 13146-2:2012, Railway applications - Track - Test methods for fastening systems - Part 2: Determination of torsional resistance [11]
SRPS EN 13146-3:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 3: Određivanje prigušenja udarnog opterećenja		EN 13146-3:2012, Railway applications - Track - Test methods for fastening systems - Part 3: Determination of attenuation of impact loads [12]
SRPS EN 13146-4:2015, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 4: Ispitivanje uticaja ponavljanja opterećenja	Objavljen (<i>Published</i>) 28.07.2015	EN 13146-4:2012+A1:2014, Railway applications - Track - Test methods for fastening systems - Part 4: Effect of repeated loading [13]
SRPS EN 13146-5:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 5: Određivanje električnog otpora	Objavljen (<i>Published</i>) 24.06.2013	EN 13146-5:2012, Railway applications - Track - Test methods for fastening systems - Part 5: Determination of electrical resistance [14]
SRPS EN 13146-6:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 6: Uticaj agresivne sredine		EN 13146-6:2012, Railway applications - Track - Test methods for fastening systems - Part 6: Effect of severe environmental conditions [15]
SRPS EN 13146-7:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 7: Određivanje sile pritezanja		EN 13146-7:2012, Railway applications - Track - Test methods for fastening systems - Part 7: Determination of clamping force [16]
SRPS EN 13146-8:2013, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 8: Ispitivanje pod saobraćajem		EN 13146-8:2012, Railway applications - Track - Test methods for fastening systems - Part 8: In service testing [17]
SRPS EN 13146-9:2011, Primene na železnici - Kolosek - Postupci ispitivanja sistema šinskih pričvršćenja - Deo 9: Određivanje krutosti	Objavljen (<i>Published</i>) 30.09.2011	EN 13146-9:2009+A1:2011, Railway applications - Track - Test methods for fastening systems - Part 9: Determination of stiffness [18]

2 METODE ISPITIVANJA SISTEMA ŠINSKIH PRIČVRŠĆENJA

S obzirom na to što su sistemi pričvršćenja značajni za bezbednost, potrebno je da postoje standardne procedure za ocenu njihovih tehničkih karakteristika u uslovima normalnog korišćenja. Očigledno je da se realni uslovi u koloseku ne mogu uvek u potpunosti simulirati u laboratorijskim ispitivanjima u EN 13146 Delovi 1–7 [10–16] i Deo 9 [18]. Stoga, tehničke karakteristike sistema šinskih pričvršćenja na evropskoj železničkoj mreži određuju se metodama laboratorijskih ispitivanja i ispitivanjem pod saobraćajem (Deo 8 [17]), u skladu sa serijom standarda EN 13146. Ove procedure ispitivanja primenjuju se na kompletan sklop pričvršćenja. Definicije termina koji se koriste u seriji EN 13146 navedene su u evropskom standardu EN 13481-1 [1].

Nakon sprovođenja merenja prema [10–18], neophodno je sastaviti izveštaje o ispitivanjima koji sadrže informacije, u skladu sa zahtevima relevantnog dela serije standarda.

2.1 Određivanje otpora podužnom pomeranju šine

Evropski standard EN 13146-1 [10] određuje procedure laboratorijskih ispitivanja za određivanje maksimalne aksijalne sile koja deluje na šinu pričvršćenu pomoću sklopa šinskog pričvršćenja za prag, dugački prag skretničke građe ili element čvrste kolosečne podloge, bez pojave neelastičnih pomeranja šine (slika 1). Navedene procedure ispitivanja primenjuju se na kompletan sklop pričvršćenja, imajući u vidu sledeće:

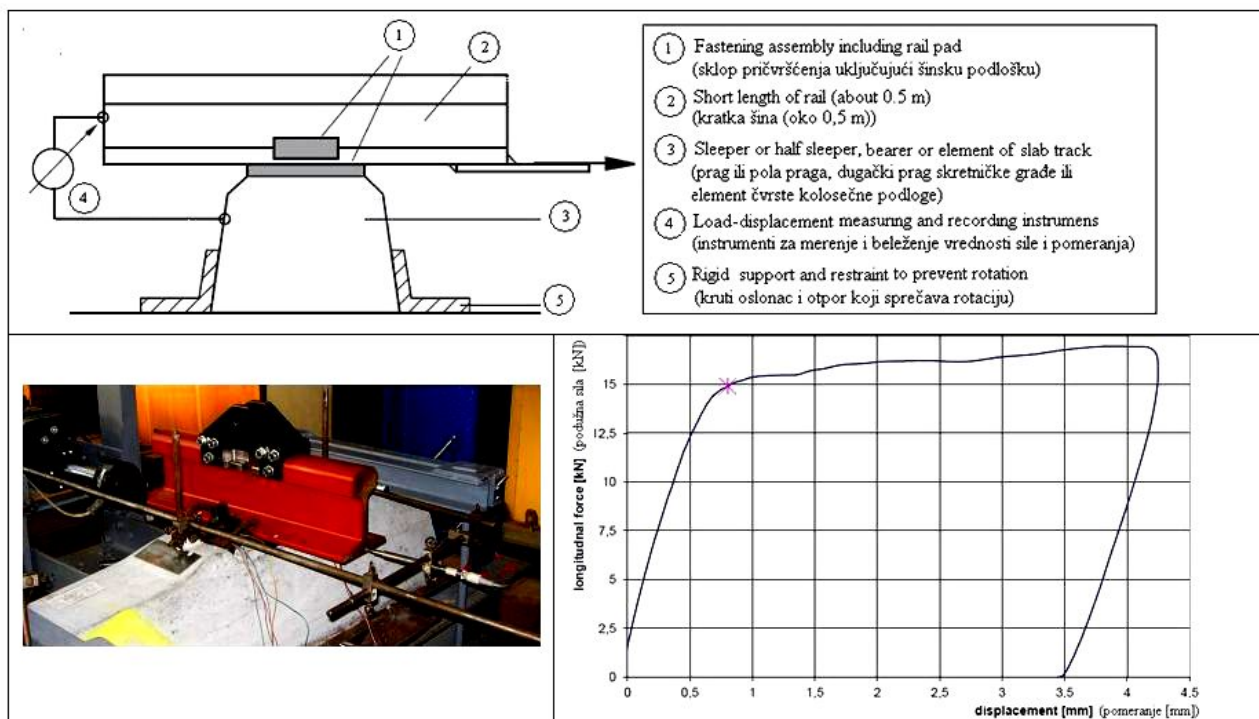
2 TEST METHODS FOR RAIL FASTENING SYSTEMS

Since fastening systems are safety critical, there is a need to have a standardised procedure to evaluate their performance in normal use. It is obvious that the real conditions in track cannot always be simulated in laboratory tests from EN 13146 Parts 1 to 7 [10 - 16] and Part 9 [18]. Consequently, performance of rail fastening systems on European railway network is determined by laboratory test methods and in service testing (Part 8 [17]) in accordance with the EN 13146 standard series. These test procedures are applied to a complete fastening assembly. The definitions of the terms used in the EN 13146 series were specified in the EN 13481-1 European Standard [1].

After performing the measurements according to [10 - 18], it is necessary to draw up a test reports, which includes information in accordance with the requirements of the relevant part of standard series.

2.1 Determination of longitudinal rail restraint

The European Standard EN 13146-1 [10] specifies a laboratory test procedure for determination of maximum axial load that can be applied to a rail, secured to a sleeper, bearer or element of slab track by a rail fastening assembly, without non-elastic displacement of the rail (Figure 1). The specified test procedure applies to a complete fastening assembly taking into account the following:



Slika 1. Postavka ispitivanja za određivanje otpora podužnom pomeranju šine i primer dijagrama sila-pomeranje (sa izmerenim otporom podužnom pomeranju šine 15 kN) [21]

Figure 1. Test arrangement for determination the longitudinal rail restraint and an example of force-displacement diagram (with measured longitudinal rail restraint 15 kN) [21]

- procedura ispitivanja meri podužni otpor šine za diskretne sisteme pričvršćenja sa šinom fiksiranom za oslonac (prag, dugački prag skretničke građe ili element čvrste kolosečne podloge) u diskretnim intervalima;
- procedura ispitivanja meri podužnu krutost za athezivne sisteme pričvršćenja sa „utopljenom” šinom (embedded rail).

2.2 Određivanje otpora zaokretanju šine

Evropski standard EN 13146-2 [11] određuje proceduru laboratorijskog ispitivanja za određivanje torzionog otpora za kompletan sklop pričvršćenja, koji se meri kao momentan potreban da se šina zaokrene za 1° u ravni koja je paralelna oslončkoj podlozi (slika 2). Dobijene vrednosti torzionog otpora koriste se u proračunima stabilnosti koloseka.



Slika 2. Postavka ispitivanja za određivanje otpora zaokretanju šine i primer dijagrama otpora zaokretanju šine
Figure 2. Test arrangement for determination of torsional resistance and an example of torsional resistance diagram

2.3 Određivanje prigušenja udarnog opterećenja

Evropski standard EN 13146-3 [12] određuje proceduru laboratorijskog ispitivanja za poređenje naprezanja izazvanih korišćenjem referentne šinske podloške s malim prigušenjem i podloške koja se ispituje u sistemu pričvršćenja. Udarno opterećenje nanosi se tegom koji pada na glavu šine (slika 3). Šina je pričvršćena za betonski prag ili dugački betonski prag skretničke građe.

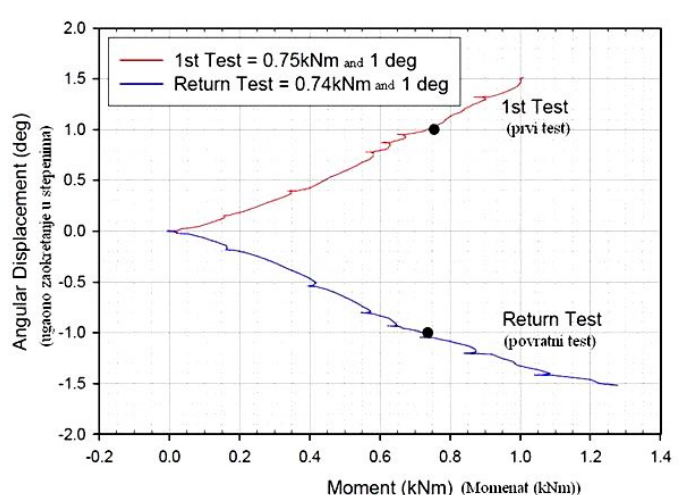
2.4 Ispitivanje uticaja ponavljanja opterećenja

Evropski standard EN 13146-4 [13] određuje proceduru za laboratorijsko ispitivanje delovanja pokretnog opterećenja koje se ponavlja u ciklusima i koje simulira opterećenje koloseka od saobraćaja (slika 4). Rezultati ispitivanja koriste se za ocenu dugoročnog ponašanja sistema direktnih šinskih pričvršćenja, u kojima je šina pričvršćena za oslončku podlogu s podložnom pločom ili bez nje (direktni sistemi pričvršćenja prema [1]). Uz ostale neophodne informacije, izveštaj o ispitivanju sadrži rezultate vizuelne inspekcije nakon ispitivanja (slika 5),

- the test procedure measures the longitudinal rail restraint for discrete fastening systems, with rail fixed to a supporting base (sleeper, bearer or element of slab track) at discrete intervals, and
- the test procedure measures the longitudinal stiffness for an adhesive fastening system with an embedded rail.

2.2 Determination of torsional resistance

EN 13146-2 European Standard [11] specifies a laboratory test procedure to determine torsional resistance of complete fastening assembly, which is measured as the moment necessary to rotate a rail through 1° in a plane parallel to the base of the support (Figure 2). The obtained value of torsional resistance is used in track stability calculations.



2.3 Determination of attenuation of impact loads

EN 13146-3 European Standard [12] specifies laboratory test procedures for comparing the strains induced with a low attenuation reference rail pad and with the test pad in the fastening system. An impact load is applied by dropping a mass onto the rail head (Figure 3). Rail is fastened to a concrete sleeper or bearer.

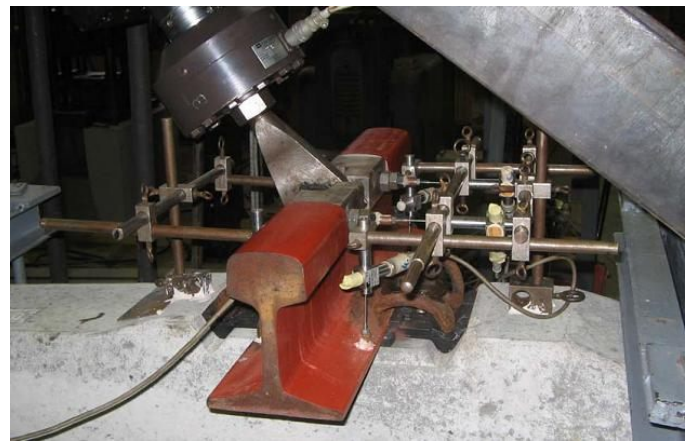
2.4 Determination of effect of repeated loading

EN 13146-4 European Standard [13] specifies a laboratory test procedure for applying repeated loading which simulates the load caused by traffic on railway track (Figure 4). This test is used for assessing the long term performance of fastening system in which a rail is directly secured to the supporting structure with or without a baseplate (“direct fastening systems” as in [1]). In addition to other necessary information, test report contains result of visual inspection after the test (Figure 5), mean vertical static stiffness before and after cyclic



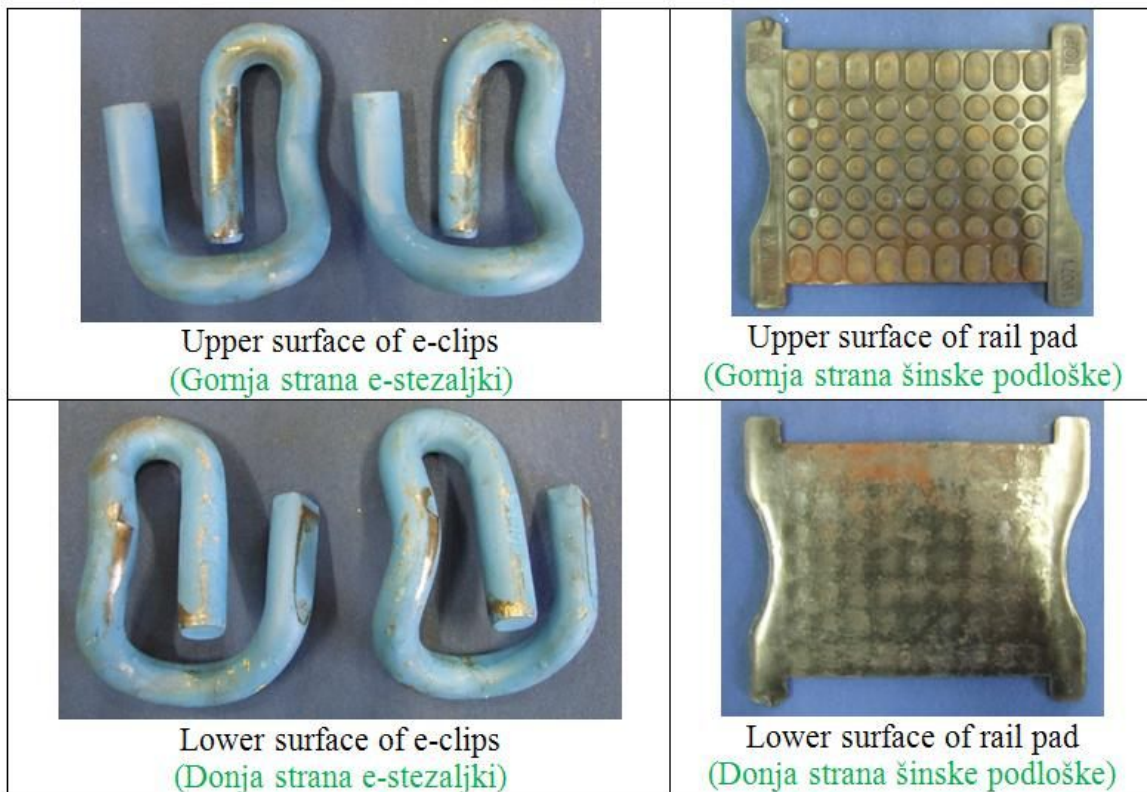
Slika 3. Postavka ispitivanja za određivanje prigušenja udarnog opterećenja

Figure 3. Test arrangement for determination of attenuation of impact loads



Slika 4. Laboratorijsko ispitivanje sa ponavljanjem opterećenja [21]

Figure 4. Laboratory test with repeated loading [21]



Slika 5. Elementi pričvršćenja nakon ispitivanja sa ponavljanjem opterećenja

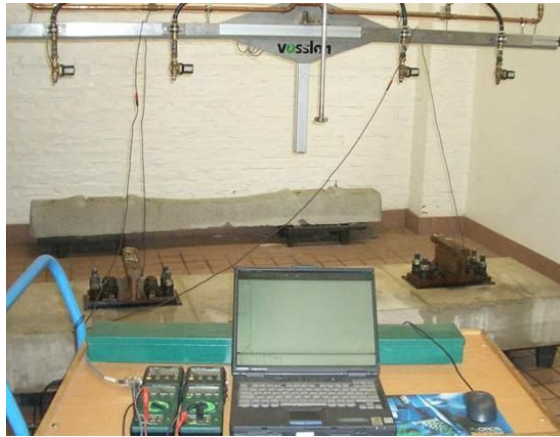
Figure 5. Fastening elements after repeated load test

srednju vertikalnu statičku krutost pre i posle ciklusa opterećenja, podužni otpor šine pre i posle ciklusa opterećenja, silu pritezanja pre i posle ciklusa opterećenja, srednje dinamičko pomeranje šine na početku i na kraju ispitivanja pomoću ponavljanja opterećenja, srednje zaostalo pomeranje pri maksimalnom opterećenju na početku i na kraju ispitivanja pomoću ponavljanja opterećenja.

loading, longitudinal rail restraint before and after cyclic loading, clamping force before and after cyclic loading, mean dynamic rail displacement at the beginning and the end of the repeated load test, mean residual displacement at maximum load at the end of the repeated load test.

2.5 Određivanje električnog otpora

Evropski standard EN 13146-5 [14] određuje proceduru za laboratorijsko ispitivanje za određivanje električnog otpora u vlažnim uslovima. Električni otpor meri se između dve kratke šine koje su pričvršćene za oslonac (čelični ili betonski prag, dugački prag skretničke građe ili element čvrste kolosečne podloge), dok se ceo oslonac i pričvršćenja prskaju vodom kontrolisanom brzinom (slika 6).



Slika 6. Određivanje električnog otpora u vlažnim uslovima u laboratoriji
Figure 6. Determining the electrical resistance in wet conditions in laboratory

2.5 Determination of electrical resistance

EN 13146-5 European Standard [14] specifies a laboratory test procedure for determining electrical resistance in wet conditions. The electrical resistance between two short lengths of rail fastened to the support (steel or concrete sleeper, bearer or element of slab track) is measured whilst the whole support and fastenings are sprayed with water at a controlled rate (Figure 6).

2.6 Uticaj agresivne sredine

Evropski standard EN 13146-6 [15] određuje proceduru laboratorijskog ispitivanja za određivanje uticaja agresivne sredine na sistem pričvršćenja (slika 7). Tokom ispitivanja, ceo sklop pričvršćenja izložen je dejstvu slanog spreja (tzv. so-sprej) i beleži se efekat lakog rasklapanja i ponovnog sklapanja, kao i stanje pojedinačnih komponenata. Izveštaj o ispitivanju sadrži promene u izgledu svake komponente tokom ispitivanja i svaku nemogućnost rasklapanja i ponovnog sklapanja sistema pričvršćenja. Buduće izmene ovog standarda treba da uključe procedure za ispitivanja koja obuhvataju i ostale uticaje sredine.



Slika 7. Oprema za ispitivanje pomoću slanog spreja
Figure 7. The equipment for the salt spray test

2.6 Effect of severe environmental conditions

EN 13146-6 European Standard [15] specifies a laboratory test procedure for determining the effects of severe environmental conditions on the fastening system (Figure 7). During the test, the complete fastening assembly is exposed to a salt spray and the effect on ease of dismantling, and reassembly, and condition of individual components is recorded. Test report includes change in appearance of each component during the test and any failure to dismantle or reassemble the fastening system. The future revisions of this standard should include test procedures for covering other environmental conditions.

2.7 Određivanje sile pritezanja

Evropski standard EN 13146-7 [16] određuje procedure za laboratorijsko ispitivanje za određivanje sile pritezanja (*sila koja se nanosi na gornju površ nožice šine delovanjem stezaljki sklopa pričvršćenja* [1]) koja deluje na nožicu šine. Sila pritezanja za kompletan sklop pričvršćenja određuje se merenjem sile potrebne za odvajanje šine od površi na koju je oslonjena (slika 8). Procedura ispitivanja može se primeniti za sisteme pričvršćenja s podložnom pločom i bez nje na pragovima, dugačkim pragovima skretničke građe i elementima čvrste kolosečne podloge.



Slika 8. Postavka ispitivanja za merenje vertikalne sile neophodne za odvajanje šina od osloničke konstrukcije u laboratoriji

Figure 8. Test arrangement for measuring the vertical force necessary to separate the rail from support structure in laboratory

2.7 Determination of clamping force

EN 13146-7 European Standard [16] specifies laboratory test procedures for measuring clamping force ("force applied to the upper surface of one rail foot by the fastening assembly clips" as in [1]) acting on the foot of a rail. The clamping force for a complete rail fastening assembly is determined by measuring the force necessary to separate the rail from the surface on which it is supported (Figure 8). The test procedure is applicable to fastening systems with and without baseplates on sleepers, bearers and elements of slab track.

2.8 Ispitivanje pod saobraćajem

Evropski standard EN 13146-8 [17] određuje procedure koje se mogu primeniti za poređenje tehničkih karakteristika u koloseku novog ili modifikovanog sistema pričvršćenja sa sistemom čije su tehničke karakteristike poznate. Sistem pričvršćenja koji se ispituje ugrađuje se u kolosek u isto vreme i pod istim uslovima (isti kvalitet šinskog čelika i profil šine, pragovi, dugački pragovi skretničke građe ili čvrsta kolosečna podloga od istog materijala i prema istom projektu, kao i položaj u koloseku sa sličnim uslovima geometrije koloseka i uslovima saobraćaja) kao i referentni sistem pričvršćenja. Dužina test-deonice ne treba da bude kraća od 500 pragova sa ugrađenim sistemom pričvršćenja koje se ispituje i 500 pragova sa ugrađenim referentnim sistemom pričvršćenja (po 200 pragova za metro sistem) ili njihovim ekvivalentom (kolosek na čvrstoj podlozi). Ispitivanje treba da traje toliko koliko je potrebno da određeni saobraćaj prođe preko koloseka koji se ispituje (npr. 20×10^6 bruto tona u koloseku s maksimalnim osovinskim opterećenjem > 100 kN), a ne sme biti kraće od godinu dana. Za vreme ispitivanja, svaki sistem pričvršćenja treba da se održava u skladu sa instrukcijama proizvođača. Inspekcija sistema pričvršćenja koji se ispituje i referentnog sistema pričvršćenja uključuje:

2.8 In service testing

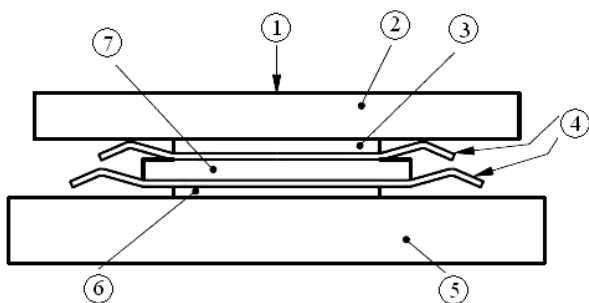
EN 13146-8 European Standard [17] provides a procedure which can be used to compare the performance of new or modified fastening systems in track with systems whose performance is known. The fastening system under test is installed in track at the same time and at the same conditions (the same grade and section of rail, sleepers, bearers or slab track of the same material and design, as well as location in track with similar geometry and service conditions) as a reference fastening system. Length of the test section should not be less than 500 sleepers with installed test fastening system and 500 sleepers with installed reference fastening system (200 sleepers each on metro systems), or their equivalent (slab track). Duration of the test corresponds to the traffic dynamics required to pass over the test track (e.g. 20×10^6 gross t in track with maximum axle loads > 100 kN) and shall not be less than one year. During the test each fastening system shall be maintained in accordance with the manufacturer's instructions. Inspection of the test and reference fastening systems includes:

- merenje širine koloseka;
- podužno pomeranje šine, relativno u odnosu na prag ili čvrstu kolosečnu podlogu i maksimalni raspon dnevne temperature;
- uticaj na performanse signalnih sistema;
- silu pritezanja (na ne manje od deset sklopova) korišćenjem metode ispitivanja u koloseku, koju preporučuje proizvođač;
- sigurnost veze s pragovima;
- stanje na glavi šine;
- stanje pragova uključujući zonu oslanjanja šine na prag;
- stanje pojedinačnih komponenata pričvršćenja;
- jednostavno ugrađivanje i demontiranje korišćenjem alata po preporuci proizvođača.

2.9 Određivanje krutosti

Evropski standard EN 13146-9 [18] daje zajedno metode ispitivanja za merenje krutosti podloški i sklopa pričvršćenja pod statičkim, niskofrekventnim i visokofrekventnim dinamičkim opterećenjem. Postavka ispitivanja za podloške prikazana je na slici 9.

Procedure ispitivanja za kompletan sklop šinskog pričvršćenja sadrže procedure statičkog ispitivanja, dinamičkog niskofrekventnog i dinamičkog visokofrekventnog ispitivanja (slika 10).



- track gauge measurement,
- longitudinal movement of rail, relative to the sleeper or slab support, and maximum daily temperature range,
- effect on performance of signalling systems,
- clamping force (on not less than 10 assemblies) using the manufacturer's recommended test method for use in track,
- security of attachment to the sleepers,
- condition of the rail head,
- condition of sleepers including rail seat area,
- condition of individual fastening components,
- ease of assembly and removal using the tools recommended by the manufacturer.

2.9 Determination of stiffness

EN 13146-9 European Standard [18] provides together test methods for measuring the stiffness of pads and fastening assemblies under static, low frequency and high frequency dynamic loading. Test arrangement for pads is shown in Figure 9.

Test procedures for complete rail fastening assemblies include static test procedure, dynamic low frequency test and dynamic high frequency test (Figure 10).

- ① force applied normal to the test pad
(sila koja upravno naneseena na testiranu podlošku)
- ② metal plate (metalna ploča)
- ③ upper load distribution plate
(gornja ploča za raspodelu opterećenja)
- ④ abrasive cloth (abrazivna tkanina)
- ⑤ base (osnova)
- ⑥ lower load distribution plate /if necessary/
(donja ploča za raspodelu opterećenja /ako je neophodno/)
- ⑦ pad to be tested (podloška koja se testira)

Slika 9. Postavka ispitivanja za merenje krutosti podloške
Figure 9. Test arrangement for measuring the stiffness of pad



Slika 10. Postavka ispitivanja za dinamičku krutost kompletnog sklopa pričvršćenja
Figure 10. Dynamic stiffness test arrangement for complete rail fastening assemblies

Dobijena vrednost krutosti koristi se u proračunu stabilnosti koloseka.

The obtained value of stiffness is used in track stability calculations.

3 TEHNIČKI USLOVI ZA SISTEME ŠINSKIH PRIČVRŠĆENJA ZA BETONSKE PRAGOVE

Definicije termina korišćene u seriji EN 13481 navode se u evropskom standardu EN 13481-1 [1]. U skladu sa [1], *sistem pričvršćenja jeste sklop komponenata koji pričvršćuje šinu za podlogu i zadržava je u zahtevanoj poziciji uz omogućavanje potrebnog vertikalnog, bočnog i podužnog pomeranja.*

Ova serija standarda razmatra specifične zahteve za sisteme pričvršćenja u zavisnosti od tipa oslonache konstrukcije (betonski pragovi [2], drveni pragovi [3], čelični pragovi [4], čvrsta kolosečna podloga [5]), kao i zahteve za specijalne sisteme pričvršćenja (za prigušenje vibracija [6], skretnice i ukrštaje, te šine vođice [7] i za kolosek za teška osovinska opterećenja [8]).

S obzirom na to što su u primeni najčešće sistemi pričvršćenja za betonske pragove u zastoru od tucanika, u radu se prikazuju tehnički uslovi za sisteme pričvršćenja u skladu sa [2]. Ovi zahtevi primenjuju se na glavnim prugama, kao i za lake šinske sisteme u skladu s tabelom 3.

3 PERFORMANCE REQUIREMENTS FOR FASTENING SYSTEMS ON CONCRETE SLEEPERS

The definitions of the terms used in EN 13481 European Standard series were specified in EN 13481-1 [1]. In accordance with [1], *“fastening system is assembly of components which secures a rail to the supporting structure and retains it in the required position whilst permitting any necessary vertical, lateral and longitudinal movement”.*

This standard series considers specific requirements for fastening systems depending on the type of supporting structure (concrete sleepers [2], wood sleepers [3], steel sleepers [4], slab track [5]), as well as requirements for special fastening systems (for attenuation of vibration [6], switches and crossings and check rails [7] and for track with heavy axle loads [8]).

Since the fastening systems on concrete sleepers in ballasted track are usually in use, the paper presents performance requirements for fastening systems in accordance with [2]. These requirements apply to main lines, as well as to light rail systems according to Table 3.

Tabela 3. Kategorije pričvršćenja u skladu sa [1, 2]
Table 3. Fastening categories in accordance with [1, 2]

Kategorije sistema pričvršćenja (Categories of fastening system)		A	B	C	D	E
Tipična maksimalna brzina [km/h] (Typical maximum speed [km/h])		100	140	250	≥250	200
Osovinsko opterećenje [kN] (Axle load [kN])	Tipično [1] (Typical [1])	100	160	225	180	300
	Maksimum [2] (Maximum [2])	130	180	260	260	350
Radijus krivine [m] (Curve radius [m])	Tipično [1] (Typical [1])	80	100	400	800	150
	Minimum [2] (Minimum [2])	40	80	150	400	150
Tipičan profil šine (Typical rail section)		40E1	54E1	60E1	60E1	60E1
Tipičan razmak pragova [m] (Typical sleeper spacing [m])		0.8	0.6	0.6	0.6	0.6
Napomena: Maksimalno osovinsko opterećenje za kategorije A i B se ne primenjuje za vozila za održavanje (Note: The maximum axle load for A and B categories does not apply to maintenance vehicles)						

Ovi tehnički uslovi primenjuju se za direktne i indirektno sisteme pričvršćenja koji deluju na nožicu i/ili vrat šine (slika 11). Nadalje, oni se primenjuju za profile šine u skladu sa [22] (izuzev 49E4) i u skladu sa [23]. Treba naglasiti i to da se ovaj standard ne primenjuje za krute sisteme pričvršćenja (npr. K kruti sistem pričvršćenja koji je često zastupljen na prugama u Srbiji).

These requirements apply to direct and indirect fastening systems which act on the foot and/or web of the rail (Figure 11). Further, they apply for the rail sections in accordance with [22] (excluding 49E4) and according to [23]. It should be noted that this standard is inapplicable to rigid fastening systems (e.g. K fastening system which is still mostly in use on railway lines in Serbia).



*Slika 11. Sistem pričvršćenja koji pridržava vrat šine
(Vanguard – Pandrol sistem pričvršćenja, snimljeno u stanici Beograd Centar, 2016)*

*Figure 11. Fastening system supporting the rail web
(Vanguard – Pandrol fastening system, foto taken in Beograd Centar station, 2016)*

Tehnički uslovi za sisteme pričvršćenja za korišćenje na betonskim pragovima koloseka u zastoru od tucanika obuhvataju podužni otpor šine, otpor zaokretanju šine (torzioni otpor), prigušenje udarnog opterećenja, uticaj ponavljanja opterećenja, električni otpor sistema pričvršćenja i praga, uticaj izloženosti agresivnim uslovima sredine, ukupne dimenzije, uticaj tolerancija sistema pričvršćenja na širinu koloseka, silu pritezanja i ispitivanje pod saobraćajem.

Zahtevani podužni otpor šine zavisi od ograničenja za brzinu i specijalnih zahteva konstrukcije donjeg stroja. U tom smislu, podužni otpor šine ne treba da bude manji od 7 kN (kontrolisano na osnovu procesa merenja u skladu sa EN 13146-1) na konvencionalnim prugama i ne treba da bude manji od 9 kN na prugama za velike brzine (≥ 250 km/h).

U skladu s projektom konstrukcije kolosečne podloge, minimalni uslovi za podužni otpor mogu da se redukuju na osnovu ugovora kupca i proizvođača. Na primer, korišćenje dilatacionih sprava za sprečavanje prekomernih podužnih pomeranja i sila na dugačkim železničkim mostovima je skupo i loše rešenje u pogledu bezbednosti saobraćaja i udobnosti, kao i troškova održavanja. Zbog toga se mogu primeniti alternativna rešenja sistema pričvršćenja s redukovanim otporom podužnom pomeranju šine. Slike 12 i 13 prikazuju PANDROL® ZLR (Zero Longitudinal Restraint – nulti podužni otpor) sistem koji je projektovan tako da se ne prenesu sile s koloseka na most, da se zadrži šina u vertikalnoj poziciji, da se obezbedi bočni otpor i da se spreči prevrtanje šine.

Performance requirements for fastening systems for use on concrete sleepers in ballasted track include longitudinal rail restraint, torsional resistance, attenuation of impact loads, effect of repeated loading, electrical resistance of fastening system and sleeper, effect of exposure to severe environmental conditions, overall dimensions, effect of fastening system tolerances on track gauge, clamping force, and in-service testing.

Required longitudinal rail resistance depends on the speed limit and the special requirements of substructure. In that sense, the longitudinal rail resistance shall be not less than 7 kN (controlled over the measurement process according to EN 13146-1) on the conventional rail lines and not less than 9 kN on high-speed lines (≥ 250 km/h).

In accordance with the design of the track supporting structure, the minimum requirement for longitudinal restraint may be reduced by agreement between the purchaser and manufacturer. For example, the utilization of expansion devices to prevent excessive longitudinal displacements and forces on the long railway bridges is expensive and bad solution in regard to traffic safety and comfort, as well as maintenance costs. Therefore, it can be applied an alternative solution of fastening system with reduced rail longitudinal restraint. Figures 12 and 13 show the PANDROL® ZLR (Zero Longitudinal Restraint) system designed to keep track forces from being transmitted to bridge, to hold the rail vertically in place, to provide lateral restraint and to prevent rail rollover.

The torsional resistance is measured in accordance with [2] and the result reported.

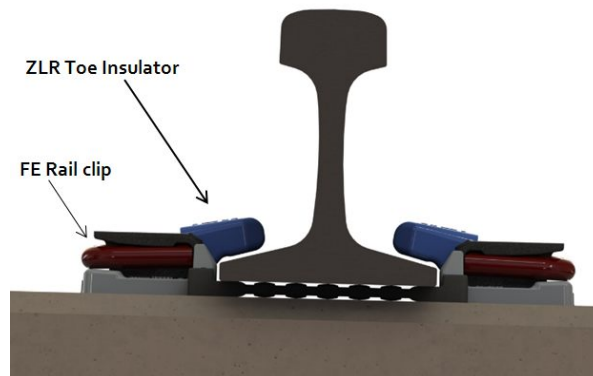
Otpor zaokretanju šine (torzioni otpor) meri se u skladu sa [2], a rezultat se unosi u izveštaj.

Za sisteme pričvršćenja koji imaju srednje ili veliko prigušenje dinamičkog opterećenja, ispitivanje treba da bude sprovedeno u skladu sa [3], a rezultat se unosi u izveštaj. Rezultati za srednje prigušenje treba da budu u rangu od 15% do 30%, a za veliko prigušenje > 30%.

Statička krutost sklopa i niskofrekventna dinamička krutost sklopa treba da se mere u skladu sa [19]. Na zahtev naručioca, statička krutost šinske podloške, niskofrekventna dinamička krutost šinske podloške i sklopovi sa visokofrekventnom dinamičkom krutošću treba da se mere u skladu sa [19] i [2] (opterećenja za merenje krutosti su definisana u [2]).

For fastening systems described as having medium or high attenuation of dynamic loads, test shall be conducted in accordance with [3] and the result reported. Test results for medium attenuation shall be in the range from 15 % to 30 %, and for high attenuation over 30 %.

The assembly static stiffness and assembly low frequency dynamic stiffness shall be measured in accordance with [19]. At the request of the customer, the rail pad static stiffness, low frequency dynamic stiffness of the rail pad and the assembly high frequency dynamic stiffness should be measured in accordance with [19] and [2] (loads for measurement of stiffness were defined in [2]).



Slika 12. Sistem pričvršćenja Pandrol ZLR sa zazorom između izolatora stezaljke i nožice šine
Figure 12. Pandrol ZLR fastening system with the gap between toe insulator and foot of rail



Slika 13. Ugrađeni sistem pričvršćenja sa stezaljkom ZLR (sistem Pandrol VIPA) na mostu
Figure 13. Installed fastening system with ZLR clips (Pandrol VIPA system) on a bridge

Uticaj ponovljenog opterećenja treba da se odredi u skladu s procedurom definisanom u [13], korišćenjem opterećenja za ispitivanje i pozicije koje su definisane u [2].

U skladu sa [13], treba obaviti sledeća merenja pre i posle ponovljenog opterećenja:

- otpor podužnom pomeranju (dozvoljena promena $\leq 20\%$);
- promena vertikalne statičke krutosti (dozvoljena promena $\leq 25\%$);
- sila pritezanja (dozvoljena promena za sisteme šinskih pričvršćenja koji deluju na nožicu šine $\leq 20\%$).

The effect of repeated loading shall be determined by the procedure defined in [13] using the test loads and positions defined in [2].

In accordance with [13], the following measurements shall be performed before and after repeated loading:

- longitudinal rail restraint (permitted change $\leq 20\%$),
- vertical static stiffness change (permitted change $\leq 25\%$), and
- clamping force (permitted change for fastening systems which act on the foot of the rail $\leq 20\%$).

Električna izolovanost ne treba da bude manja od 5 k Ω kada se meri u skladu sa [14]. Korisnik može da definiše veće vrednosti u slučaju kada se kolosek koristi kao povratni vod (smernice za struju za vuču vozila date su u [24] i SRPS EN 50122-2).

Uticaj izloženosti agresivnim uslovima sredine određuje se u skladu sa [15] na osnovu ispitivanja pomoću slanog spreja. Nakon ispitivanja, šinsko pričvršćenje treba da bude sposobno da se rasklopi bez oštećenja bilo koje komponente i da se ponovo sklopi ručnim alatom koji je namenjen za tu svrhu.

Slika 14 prikazuje anvelopu za sisteme šinskog pričvršćenja (koji deluju na nožicu šine) za betonske pragove u zastoru od tucanika i profil šine u skladu sa [22] (izuzev 49E4) i u skladu sa [23]. Ova anvelopa neophodna je da bi se sprečila kolizija s točkom uključujući vozila za održavanje.

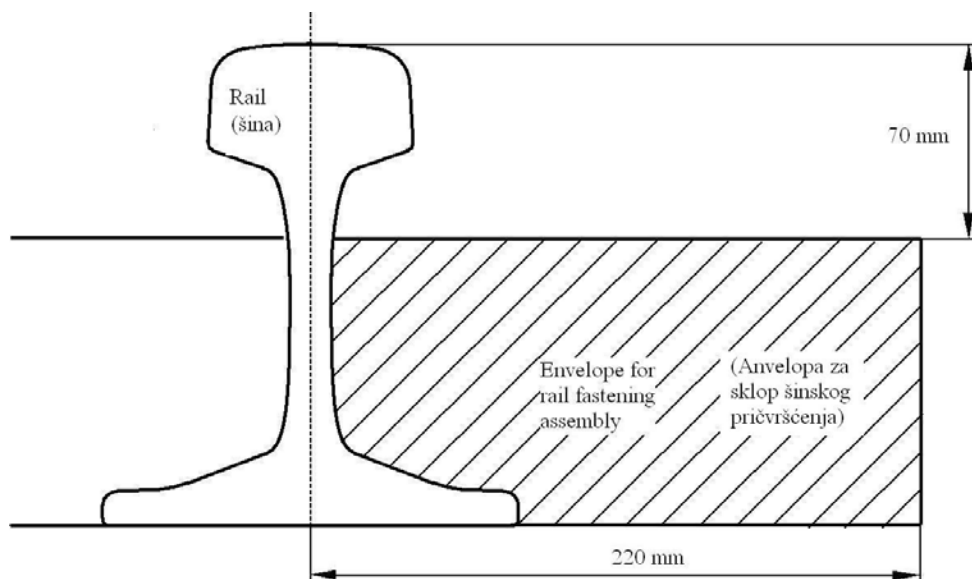
Treba napomenuti i to da za sisteme pričvršćenja koji deluju na vrat šine minimum prostora za prolaz venca točka treba da bude u skladu s nacionalnim propisima, a anvelopu sistema pričvršćenja treba da obezbedi isporučilac.

The electrical insulation shall be not less than 5 k Ω when measured in accordance with [14]. The user may specify a higher value for use with certain track circuits (guidance on traction currents is given in [24] and SRPS EN 50122-2).

Effect of exposure to severe environmental conditions is determined in accordance with [15] based on the salt spray test. After the test, the fastening assembly shall be capable of being dismantled, without failure of any component and reassembled using manual tools provided for this purpose.

Figure 14 shows the envelope for rail fastening systems (which act on the foot of the rail) for concrete sleepers in ballasted track and rail section in accordance with [22] (excluding 49E4) and [23]. This envelope is necessary to avoid interference with vehicles including track maintenance vehicles.

It should be noted that for web support fastening systems, the minimum flangeway shall comply with national regulations and the envelope of the fastening systems shall be provided by the supplier.



Slika 14. Anvelopa za sistem šinskog pričvršćenja (koji deluju na nožicu šine) za betonski prag u koloseku sa zastorom od tucanika

Figure 14. Envelope for rail fastening systems (which act on the rail foot) for concrete sleepers in ballasted track

Proizvođač treba da obezbedi tehničke crteže veze sistema pričvršćenja i praga. Promene statičke širine koloseka, koje se mogu pojaviti usled sistema pričvršćenja - ne treba da pređu ± 1 mm.

Sila pritezanja za sisteme pričvršćenja (koji deluju na nožicu šine) treba da se odredi po proceduri propisanoj u [16], a rezultati treba da se prikažu u izveštaju. Zahtevi za silu pritezanja ne mogu da se primene na sisteme pričvršćenja koji deluju na vrat šine.

Ispitivanje pod saobraćajem treba da se sprovede u skladu sa [17] - na zahtev kupca.

Druge posebne zahteve za sisteme šinskih pričvršćenja moraju da definišu korisnici.

The manufacturer shall provide a drawing of the interface between the fastening system and the sleeper. The variation in the static track gauge which can arise from the fastening system shall not exceed ± 1 mm.

Clamping force for fastening systems (acting on the rail foot) shall be determined by the procedure prescribed in [16] and the results shall be reported. The requirement for clamping force is inapplicable to web support fastening systems.

In-service testing shall be carried out in accordance with [17] at the request of the customer.

Other specific requirements for fastening system must be defined by the customer.

4 ZAKLJUČAK

U ovom radu razmatrani su tehnički zahtevi za sisteme šinskih pričvršćenja na prugama s projektovanim osovinskim opterećenjem do 350 kN, u skladu sa evropskom serijom standarda EN 13481. Ukazuje se na obavezne tehničke zahteve u skladu sa evropskim standardima i specifične zahteve, u skladu sa uslovima projekta.

Rad prikazuje tehničke uslove za sisteme pričvršćenja za betonske pragove u koloseku sa zastorom od tucanika zato što su ovi sistemi pričvršćenja najčešće u upotrebi u Srbiji.

Metode ispitivanja sistema pričvršćenja posebno su razmatrane u skladu sa evropskom serijom standarda EN 13146.

Obe pomenute serije standarda usvojio je Institut za standardizaciju Srbije kao srpske standarde SRPS EN 13481 (Delovi 1–8) i SRPS EN 13146 (Delovi 1–9). Trenutno stanje procesa harmonizacije za obe serije standarda prikazano je u tabelama 1 i 2. Primena standarda SRPS EN otežana je zbog toga što su objavljeni samo na engleskom jeziku, nisu prevedeni na srpski jezik.

Cilj rada jeste da se inženjerska javnost u Srbiji upozna s pomenutim serijama standarda i da se olakša njihova praktična primena.

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4 CONCLUSION

In this paper, technical requirements for rail fastening systems on rail lines with design axle load up to 350 kN were considered in accordance with EN 13481 European Standard series. It points to the mandatory requirements and according to the European standards and specific requirements according to the conditions of the project.

The paper presents the performance requirements for fastening systems on concrete sleepers in ballasted track since these fastening systems are commonly used in Serbia.

Test methods for fastening systems were particularly discussed in accordance with EN 13146 European Standard series.

Both of the above mentioned standard series were adopted by the Institute for Standardization of Serbia as Serbian standards SRPS EN 13481 (Parts 1 - 8) and SRPS EN 13146 (Parts 1 - 9). State of the art in the harmonization process of both standard series is shown in Tables 1 and 2. Implementation of SRPS EN standards is difficult because they were published only in English.

The aim of the paper is to introduce engineering public in Serbia with mentioned two standard series and to facilitate their practical implementation.

ACKNOWLEDGEMENT

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REZIME

METODE ISPITIVANJA I TEHNIČKI USLOVI ZA SISTEME ŠINSKIH PRIČVRŠĆENJA ZA BETONSKE PRAGOVE

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Program rekonstrukcije i modernizacije železničke mreže Republike Srbije treba uskladiti s tehničkim uslovima evropske železničke mreže, kako bi se realizovali zahtevi interoperabilnosti železničkog sistema. Na osnovu usvojene serije standarda SRPS EN 13481 i SRPS EN 13146, analiziraju se tehnički uslovi za primenu sistema šinskih pričvršćenja za betonske pragove. Cilj rada jeste da se inženjerska javnost u Srbiji upozna s pomenutim serijama standarda i da se olakša njihova praktična primena.

Cljučne reči: železnica, sistemi šinskih pričvršćenja, metode laboratorijskih ispitivanja, ispitivanje pod saobraćajem, tehnički uslovi, harmonizacija

SUMMARY

TEST METHODS AND REQUIREMENTS FOR FASTENING SYSTEMS FOR CONCRETE SLEEPERS

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In order to realize interoperability of railway system, the reconstruction and modernization plan of railway network in the Republic of Serbia should be harmonized with technical requirements of European railway network. Performance requirements for fastening systems for concrete sleepers were analysed according to the adopted standard series SRPS EN 13481 and SRPS EN 13146. The aim of the paper is to introduce engineering public in Serbia with mentioned two standard series and to facilitate their practical implementation.

Key words: railway, fastening systems, laboratory test methods, in service testing, performance requirements, harmonization